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DIETARY FIBRE CONCENTRATE FROM CARROT POMACE: PROCESS OPTIMIZATION, ANTIOXIDATIVE AND FUNCTIONAL PROPERTIES

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ABSTRACT

Dietary fibre concentrate from carrot pomace was prepared and characterized for its physicochemical, antioxidative and functional properties. Optimization of process was done for three independent process variables i.e temperature (30-90°C) of solvent,treatment time (5-15min) and water to sample ratio (5-10) and four responses viz.total dietary fibre (TDF) , Ferric ion reducing antioxidant power (FRAP), water holding capacity (WHC) and oil holding capacity (OHC) using Box-Behnken design of response surface methodology. The results revealed that temperature witnessed most significant effect on all the responses of developed carrot fibre concentrate followed by time. The optimum process parameters for preparation of fibre concentrate were: temperature 90°C, time 15 min and water to sample ratio 8.94. These conditions yielded fibre concentrate having 73.56 % of TDF, 22.57mg/g of FRAP, 7.89 g/g of WHC and 2.50 g/g of OHC. Further characterization of fibre concentrate prepared under optimized conditions revealed that it has IDF to SDF ratio 2.87 and antioxidative activities viz. ABTS 49.22±0.21 % and DPPH 55.26±0.32% respectively. The results recommended that carrot pomace fibre concentrate have considerable antioxidant activity and functional properties and can be used as source of dietary fibre in formulation of functional foods.

Keywords: Antioxidative activities, Carrot pomace, Dietary fibre, Functional properties, Optimization

By-product utilization is an evolving study area in food industry. Many food processing industries produce very large amount of waste and residues such as peels, pomace, pods, leaves, stems, waste water etc. Large amount of waste from fruit and vegetable processing industry is produced every year, which causes trouble in its disposal. Plant waste is prone to microbial spoilage and leads to environment pollution. These fruit and vegetable by-products are good source of dietary fibre and many phytochemicals. Some of them contain more dietary fibre than their edible portions which can be utilized into food products (Goni and Hervert-Hernandez, 2011). The utilization of high nutrient fruit and vegetable by-products in processing industry for extraction of dietary fibre powder and utilization in food products leads to production of low cost functional foods. Dietary fibre powder can also be used in the pharmaceutical industries as a nutritional supplement due to the health benefit properties and associated bioactive components of dietary fibre. Another utility, in economic terms, is the potential reuse of waste by-products as a raw material for new products, thus making it possible to reduce the problems in seasonal pattern from which some sector or companies suffer. Value addition to the waste helps to curtail the price of main product, thus a direct profit to the processors and consumers. Thus, the process development for extraction of functional ingredients from fruit and vegetable by-products has practical application in food industry.

Dietary fibre is edible part of plant substances or similar polysaccharides that are resistant to hydrolysis and absorption by various digestive enzymes present in small intestine of human, with complete or partial digestion in large intestine (Nawirska and Kwasniewska, 2005, Sangnark and Noomhorm, 2004). Dietary fibre categorised as soluble/viscous/fermentable was known as soluble dietary fibre (SDF) and insoluble/nonviscous/ slowly fermentable as insoluble dietary fibre (IDF) (Ramulu and Rao, 2003). The IDF is responsible for intestinal regulation and water absorption, whereas the SDF may affect the fat metabolism and is also linked with the decreasing cholesterol level in blood (Schneeman, 1987). High dietary fibre consumption allows the prevention or treatment of atherosclerosis, coronary artery disease (CAD), colorectal cancer, diabetes and obesity (Borchani *et al.,* 2011). Daily recommended consumption of dietary fibre of about 25-30 g/ person has been recommended (Figuerola *et al.,* 2005). Some organizations recommended 35-40 g/day high dietary fibre to prevent heart diseases (Gorinstein *et al.,* 2001).

The most widely use dietary fibre products are derived from cereals (Vergara-Valencia *et al.,* 2007). Fruit and vegetable dietary fibres have superior nutritional quality than cereals due to presence of

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higher total dietary fibre (TDF) and SDF content, water holding capacity (WHC) and oil holding capacity (OHC) (Larrauri, 1999). In developing countries, 35-60% of TDF intake is provided by cereals, while only 7-15% through fruits and vegetables (Bingham, 1987). For formulation of dietary fibre food product, SDF content should be between 30-50% of total dietary fibre (Spiller 1986; Eastwood, 1987). Therefore, dietary fibre from fruit and vegetable sources could be more suitable for formulation of high dietary fibre food products.

Carrot (*Daucus carota* L.) mainly grown for its fleshy roots is rich in carotene thiamine, riboflavin, protein, potassium and sodium (Wolf, 1996). Processing of carrot results in generation of 30 to 40% of carrot pomace which is usually discarded or used as animal feed. Despite having the potential for value addition out of by- product of carrot, it has not been commercially explored in most of the developing countries. In view of above, the present study was undertaken with objective to optimize the process variables for preparation of dietary fibre concentrate from carrot pomace and to characterize it for physicochemical, antioxidative and functional properties for its utilization as potential ingredient in formulation of functional foods.

MATERIALS AND METHODS

This study was undertaken in the laboratory of Department of Processing and Food Engineering, Punjab Agricultural University, Ludhiana, Punjab, India. Total Dietary Fibre Assay kit (TDF100-1KT) was procured from Sigma Aldrich Chemicals Company, USA. Gallic acid, 1,1-diphenyl-2-picrylhydrazyl (DPPH), 2,2-azinobis-(3-ethylbenzothiazoline-6-sulfonate) (ABTS), 2-deoxy-D-ribose, 1,10 phenanthroline, potassium ferricyanide, rutin, were purchased from Sisco Research Laboratories Pvt Ltd. . All chemicals used in the present study were of analytical grade. Fresh carrot pomace was collected from local juice shop.

Preparation of dietary fibre concentrate

Carrot pomace was dipped in warm water at different temperatures for different time periods using different water to sample ratios according to experimental design and then dried in tray drier at 50°C for 12-14 h. Dried sample was ground to 400-500 µm particle size using hammer mill.

Experimental design and optimization

A Box-Behnken design of response surface design using Design Expert software version 7.0 (Statease Inc., Minneapolis, USA) was chosen to find out best experimental conditions. In the experimental design three independent process variables viz. temperature (30-90°C) of solvent , time (5-15 min) of treatment and water to sample ratio (5-10) were chosen to evalulate their effect on fibre yield and on its chemical attributes , antoxidative and functional properties. Using this design for three factors, 15 runs were planned for experimentation.

Optimization of process parameters was done based on four responses i,e total dietary fibre (TDF), ferric ion reducing antioxidant power (FRAP), water holding capacity (WHC) and oil holding capacity (OHC). Response surface methodology was applied to the experimental data using a Design-Expert version 7.0.0 for optimization. The same software was used for the generation of response surface plots as well as superimposition of 3-D plots and for optimization of process variables. 3-D plots were generated for different interactions for any two indepedent variables, while holding the value of other variables as constant (at the central value). Such three-dimensional plots could give accurate geometrical representation and helpful in providing provide useful information about the behaviour of the system within the experimental design (Cox and Cochran 1964, Montgomery 2004). The optimization of the fibre extraction process aimed at finding the levels of factors viz.extraction temperature, time and water:sample which could give maximum value of TDF, FRAP, WHC and OHC.

Estimation of dietary fibre content

Enzymatic gravimetric method (AOAC, 2000) was used for estimation of insoluble dietary fibre (IDF) and soluble dietary fibre (SDF) content using total Dietary Fibre Assay kit (TDF100-1KT) procured from Sigma Aldrich Chemicals Company, USA. Total dietary fiber (TDF) was calculated as the sum of SDF and IDF.

Physico-chemical quality analysis of fibre concentrate

The moisture content in the sample was determined by the hot air oven single stage method by keeping 5 g in an oven at 105°C till the constant weight and calculated by measuring the ratio of loss in weight to weight of sample and then multiplied by 100 (AOAC, 2000). For estimating ash content, 3 g sample was first incinerated on hot plate until there were no more fumes and then was kept in a crucible and placed in muffle furnace at 525°C for 5 h. Crude protein content was estimated by measuring nitrogen content by kjeldhal method and multiplying it by 6.25 (AOAC, 2000). Crude fat content was estimated by Soxhlet method(AOAC, 2000). Total free sugars were estimated by method of Dubois *et al.* (1956). Colour of fibre concentrate was determined by Miniscan XE plus Hunter lab Colorimeter (U.S.A.). Colour was measured in terms of 'L', 'a' and 'b' value after calibrating the colorimeter with standard

white and black plates.

Estimation of phenolic content of fibre concentrate

Phenolic content of fibre concentrate was determined as described by Devi *et al.* (2019). Phenolic compounds were extracted by crushing carrot sample (1g) and refluxed with 80% methanol (5ml) for 1 h. The refluxed sample was filtered and the volume was made 10 ml with 80% methanol and was used for estimation of phenolic compounds. For estimation of total phenols, methanolic extract (0.5 ml) was evaporated to dryness and the residue was dissolved in 6.5ml of distilled water. To this, Folin's reagent (0.5 ml) was added and shaken thoroughly. After 5 min, saturated solution of Na_2CO_3 (1 ml) was added and the reaction mixture was incubated at room temperature for 1 h. The absorbance of blue color was read at 760 nm against a blank. The concentration of total phenol was determined from standard curve prepared simultaneously using gallic acid (10-50µg). Phenols and Flavonoids were estimated by the method described by Devi *et al.* (2019)and their content was measured by the preparing standard curve simultaneously using gallic acid (10-100 µg) and quercetin (10-100 µg), respectively. The results were expressed as mg per g of dry weight.

Antioxidative properties of fibre concentrate

ABTS radical scavenging activity, was measured by the method of Re *et al.* (1999). ABTS radical scavenging activity (%) was calculated by subtracting the absorbance of extract from absorbance of blank, dividing this by absorbance of blank and multiplying by100. DPPH radical scavenging activity was measured according to the method of Yih *et al* (2009). It was measured as a decrease in the absorbance at 517 nm with respect to control and calculated by subtracting the absorbance of extracts from absorbance of control dividing it by absorbance of control and multiplying by 100. FRAP activity was estimated by using the method of Benzie *et al* (1996) and calculated by preparing the standard curve simultaneously using $FeSO_4.7H_2O$ (5-30 µg). Results were expressed in mg per g of dry weight

Analysis of functional properties of fibre concentrate

Water holding capacity (WHC) was measured by method of Robertson and Eastwood (1981) and expressed as grams of water/ gram of sample. Oil holding capacity (OHC) was measured by method of Lin *et al.* (1974). OHC was expressed as grams of oil absorbed/gram of sample (Lin *et al.,* 1974). Water swelling capacity (WSC) was measured by the method of Robertson *et al.* (2000) and expressed as ml of water/ gram of sample. For measuring water solubility method of Anderson *et al.* (1969) was employed. Water solubility expressed as weight of dry solid in supernatant as percentage of the original weight of sample.

RESULTS AND DISCUSSION

Effect of process parameters on properties of dietary fibre concentrates

Table 1 represents the biochemical and functional properties of carrot pomace fibre concentrate prepared under different experimental conditions. TDF, IDF and SDF content ranged between 53.92 to 75.55 %, 35.42 to 58.65 % and 14.60 to 18.50 %, respectively. Irrespective of experimental combinations, TDF and IDF content increased with increase in temperature, whereas decrease in SDF content was observed with increase in temperature up to 60°C which might be due to loss of SDF content during treatment in water at high temperature. The ratio of IDF: SDF was 3.47 to 1.91 under different experimental conditions indicating that carrot pomace fibre concentrate could be used for formulation of dietary fibre rich food. According to Spiller (1986) and Eastwood (1987), for formulation of dietary fibre food product SDF content should be between 30-50% of total dietary fibre. SDF: IDF ratio of 1:2 has been reported optimum for its use as functional ingredient in food products (Larrauri *et al.,* 1999, Jaime *et al., 2002*). Crude fat content in carrot pomace ranged between 1.02-1.27 % with slight decrease with increase in temperature and time. Free sugars were found between 6.16- 11.93% which decreased with increase in temperature and time. This decrease in sugars might be due to loss of free sugars during treatment with warm water (Sharoba *et al.,* 2013). Functional properties viz. WHC and OHC of fibre concentrate was ranged between 4.85 to 7.99 g/g and 1.41-2.46 g/g, respectively under different experimental combinations (Table 1). With increase in temperature and time, WHC first decreased then increased and OHC exhibited increasing trend. WHC is the quantity of water that remains bound to the hydrated fibre following of an external force (Raghavendra *et al.,* 2006). Increase and decrease WHC was found in parallel to increase/ decrease of SDF content. The observation that Soluble fibre possessed higher WHC than cellulosic fibres has also been indicated by Sharoba *et al* (2013). OHC was related to chemical structure of plant polysaccharides, nature of fibre particle and IDF content of fibre (Figuerola *et al* 2005). Increase in OHC content was found with simultaneous increase in IDF content of dietary fibre concentrate. Total soluble phenols and flavanoids of extracted carrot pomace fibre concentrate decreased with increase in temperature and time of treatment and ranged between 1.36-4.05 mg/g and 0.77-2.65 mg/g, respectively under different experimental combinations.

Table 1. Effect of different experimental conditions on TDF, fat, free sugars and functional properties of carrot pomace fibre concentrate

Temp. (°C)	Time (min.)	W:S	TDF (%)	IDF (%)	SDF (%)	SDF: IDF	Crude Fat (%)	Total Free sugars (%)	WHC (g/g)	OHC (g/g)
30	5	7.5	53.92±0.58	35.42±0.58	18.5±0.32	1:1.91	1.27±0.01	11.93±0.16	6.05±0.03	1.41±0.01
30	10	5.0	55.29±1.12	37.89±0.56	17.4±0.23	1:2.17	1.26±0.01	11.78±0.15	5.76±0.02	1.64±0.02
30	10	10.0	55.75±1.14	39.35±0.52	17.4±0.12	1:2.6	1.27±0.04	11.47±0.13	5.21±0.01	1.74±0.02
30	15	7.5	54.81±1.06	39.31±0.47	17.5±0.29	1:2.24	1.25±0.01	11.43±0.11	5.31±0.02	1.81±0.01
60	5	5.0	54.04±1.12	39.44±0.23	15.6±0.17	1:2.52	1.27±0.05	10.85±0.11	5±0.12	1.67±0.01
60	5	10.0	55.95±0.58	40.65±0.67	15.3±0.06	1:2.65	1.22±0.01	9.98±0.12	4.92±0.06	1.67±0.01
60	10	7.5	56.75±0.20	41.85±0.46	14.9±0.12	1:2.80	1.2±0.03	9.92±0.11	4.58±0.01	1.65±0.02
60	15	5.0	58.61±0.35	44.01±0.58	14.6±0.12	1:3.01	1.15±0.01	9.65±0.13	4.85±0.03	2.03±0.02
60	15	10.0	59.03±0.6	43.63±0.52	15.4±0.16	1:2.83	1.15±0.02	9.07±0.09	5.23±0.12	2.21±0.03
90	5	7.5	62±0.58	46.3±0.52	15.7±0.12	1:2.94	1.1±0.02	8.15±0.07	5.17±0.06	2.31±0.01
90	10	5.0	67.51±0.58	50.8±0.23	15.7±0.16	1:3.23	1.07±0.02	7.36±0.10	6.02±0.03	2.34±0.02
90	10	10.0	69.32±0.87	52.52±0.41	16.8±0.12	1:3.12	1.05±0.03	6.28±0.11	6.65±0.03	2.38±0.01
90	15	7.5	75.55±0.9	58.65±0.6	16.9±0.13	1:3.47	1.02±0.01	6.16±0.10	7.99±0.02	2.46±0.01

Values are mean ±SE of three replications
Temp.: Temperature, W:S water to sample ratio,TDF: Total dietary fibre, IDF: Insoluble dietary fibre, SDF: Soluble dietary fibre, WHC: Water holding capacity, OHC: Oil holding capacity

Table 2. Effect of different experimental conditions on phenols, flavanoids and antioxidative activity of carrot pomace fibre concentrate

Temp. (°C)	Time (min.)	W:S	Phenol content (mg/g)	Total flavanoid Content (mg/g)	ABTS (%)	DPPH (%)	FRAP (mg/g)
30	5	7.5	4.05±0.03	2.65±0.01	65.18±1.10	66.2±1.12	28.63±0.42
30	10	5.0	4.01±0.01	1.42±0.01	62.57±1.04	65.86±1.03	24.54±0.42
30	10	10.0	3.57±0.02	1.16±0.03	61.57±1.04	64.6±1.35	24.03±0.52
30	15	7.5	3.17±0.04	1.01±0.02	61.16±1.06	64.03±1.03	23.36±0.53
60	5	5.0	2.73±0.02	0.92±0.02	61.1±1.0	62.72±0.58	22.36±0.62
60	5	10.0	2.12±0.01	0.85±0.03	61.08±1.02	62.43±0.6	22.54±0.51
60	10	7.5	1.9±0.03	0.84±0.04	57.09±1.02	62.37±1.12	21.51±0.54
60	15	5.0	1.83±0.02	0.84±0.02	54.02±1.01	61.46±1.03	21.33±0.33
60	15	10.0	1.83±0.01	0.82±0.01	53.25±1.14	61.29±1.05	21.24±0.6
90	5	7.5	1.82±0.01	0.79±0.01	50.28±1.05	58.04±0.58	21.42±0.41
90	10	5.0	1.77±0.03	0.78±0.02	48.59±1.01	57.41±1.24	20.51±0.22
90	10	10.0	1.68±0.02	0.77±0.03	47.83±1.01	56.78±1.10	21.45±0.41
90	15	7.5	1.36±0.03	0.77±0.01	47.71±0.73	56.5±1.06	21.51±0.51

Values are mean ±SE of three replications,
Temp.: Temperature, W:S water to sample ratio
ABTS: 2, 2'-Azino-bis(3-ethylbenzothiazoline-6-sulphonicacid) DPPH: 2,2-Diphenyl-1-picrylhydrazyl FRAP: Ferric reducing ability of plasma

By-product may contain many compounds which exhibit antioxidative activity, so several methods has been developed to estimate total antioxidative activities and more than one method should be used to get complete value of antioxidative capacity of phenolic compounds Antioxidative activities i.e. ABTS, DPPH and FRAP were 47.71 to 65.18 %, 56.50 to 66.20 % and 20.51 to 28.63 mg/g, respectively under different experimental conditions. Antioxidative activities decreased with increase in temperature and time and this decrease was parallel with decrease in phenolics. The level of extracted polyphenols and antioxidant radical efficiency might be considered adequate for overall antioxidant capacity (Vergara-Valencia *et al* 2007).

Maximum TDF, WHC and OHC of carrot pomace fibre concentrate was obtained, when treated at temperature 90°C for 15 min using water to sample ratio of 7.5, whereas maximum free sugars, phenols, flavanoids, ABTS, DPPH and FRAP was found at temperature 30°C, time 5 min and water to sample ratio 7.5 indicating that fibre content, antioxidative and functional properties were affected by experimental conditions. Sharoba *et al* (2013) reported 69.85 % TDF, 45.12 % IDF, 24.73 % SDF and 1.75 % fat in carrot pomace fibre concentrate with 19.72 g/g WHC and 3.95 g/g OHC after washing at 30°C twice.

Fitting the models

Regression analysis was carried out using Box-Behnkendesign of RSM to fit the mathematical models to the experimental data. The quadratic model obtained from regression analysis for TDF, FRAP, WHC and OHC of fibre extract in terms of coded levels of the variables was developed as under:

TDF (%) = +56.76 + 6.82*A + 2.76*B + 0.57*C + 3.165*A*B + 0.33*A*C – 0.37*B*C + 4.93*A^2 – 0.13*B^2 + 0.27*C^2

FRAP (mg/g) = +21.51 – 1.95 *A – 0.93*B + 0.065*C + 1.35*A*B + 0.36*A*C – 0.067*B*C + 1.49*A^2 + 0.73*B^2 – 0.37*C^2

WHC (g/g) = +4.58 + 0.43 *A + 0.28*B + 0.047*C + 0.89*A*B + 0.29*A*C + 0.11*B*C + 1.23*A^2 + 0.32*B^2 + 0.1*C^2

OHC (g/g) = +1.65 + 0.36 *A + 0.18*B + 0.04*C – 0.062*A*B - 0.015*A*C + 0.045*B*C + 0.23*A^2 + 0.11*B^2 + 0.13*C^2

Here A is temperature, B is time and C is water to sample ratio**.**

Table 3 showed the sum of squares values and p-values for different responses viz. TDF, FRAP, WHC and OHC. Values of 'p' less than 0.0500 indicate model terms are significant at 5% level of significance. The analysis of variance showed that the regression sum of squares are statistically significant at the level of 95% for all four parameters. Coefficients of determination, R^2, which is a measure of degree of fit, were 0.987965, 0.970135, 0.960892 and 0.987157 respectively for TDF, FRAP, WHC and OHC respectively. R^2 value for a good fit model should be at least 0.80. Thus predicted models well represented the observed values for these four parameters.

The overall model for all responses viz. TDF, FRAP, WHC and OHC is significant as for all these p values are less than 0.05. Among all variables, least p-value was found for temperature, so temperature of treatment witnessed most significant effect on all these responses followed by time of treatment. However, ratio of water to sample did not exhibit any significant effect on all the four responses (Table 3). These were affected significantly by time: time interaction ($p<0.05$).TDF, FRAP and WHC were also affected significantly by temperature: time interaction ($p<0.05$). The relationship

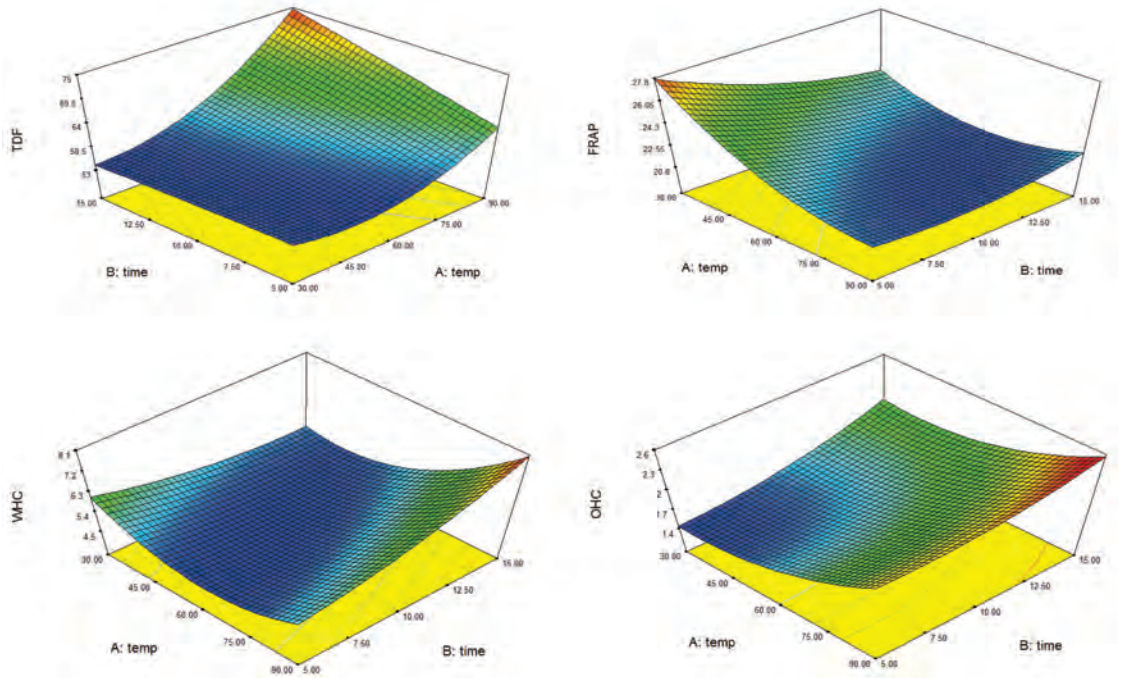

Fig. 1. Effect of temperature and time at fixed sample: water ratio on properties of fibre concentrate from carrot pomace

Table 3. ANOVA for TDF, antioxidative activity and functional properties of carrot pomace fibre concentrate

Parameters	Sum of squares			
	TDF (%)	FRAP (mg/g)	WHC (g/g)	OHC (g/g)
Model	568.2817 (0.0003)*	56.14102 (0.0027)*	11.5211 (0.0051)*	1.631415 (0.0003)*
Temperature (A)	372.781 (<0.0001)*	30.53711 (0.0002)*	1.53125 (0.0099)*	1.044013 (<0.0001)*
Time (B)	60.99601 (0.0012)*	6.975113 (0.0064)*	0.6272 (0.0491)*	0.262813 (0.0005)*
S:w ratio (C)	2.645 (0.255)	0.0338 (0.7671)	0.0180 (0.6792)	0.012 (0.1430)
AB	40.0689 (0.0030)*	7.29 (0.0059)*	3.1684 (0.0021)*	0.015625 (0.1131)
AC	0.455625 (0.5910)	0.525625 (0.2723)	0.3481 (0.1120)	0.0009 (0.6645)
BC	0.555025 (0.5545)	0.018225 (0.8275)	0.0529 (0.4864)	0.0081 (0.2257)
A^2	89.80186 (0.0005)*	8.280023 (0.0045)*	5.586092 (0.0006)*	0.210467 (0.0009)*
B^2	0.06081 (0.8423)	1.981131 (0.0621)	0.378092 (0.1009)	0.043667 (0.0238)*
C^2	0.26751 (0.6786)	0.519231 (0.2749)	0.036923 (0.5579)	0.068544 (0.0101)*
R^2	0.987965	0.970135	0.960892	0.987157
Std.dev.	1.17668	0.587924	0.306235	0.065154

*indicate significant effect. Data in parenthesis represent the p-value

Table 4. Optimized vs. experimental values of fibre content, antioxidative and functional properties of fibre concentrate

	Independent variables			Responses			
	Temp.	Time	W:S	TDF (%)	FRAP (mg/g)	WHC (g/g)	OHC (g/g)
Optimized	90	15	1:8.94	74.72	22.28	8.03	2.56
Experimental	90	15	1:8.94	73.56	22.57	7.89	2.50
Variation (%)	-	-	-	1.55	1.30	1.74	2.35

W: S – water to sample ratio

between process parameters and different responses can be illustrated graphically by 3-D plots (Fig. 1). Such plots are helpful in studying the effect of variation of factors in the studied domain and consequently in determining the optimal experimental conditions. Fig 1a-d showed the TDF content as well as OHC of fibre concentrate increased with increased in temperature and/or increasing time of treatment. These effects were more at temperature above 60 °C and after time 10 min. This might be due to solubility of simple sugars which increased with increase in temperature leaving behind pure concentrate. Also, it can be explained by thermodynamic effect of breaking connections of fibres to other biomolecules ((Bouaziz *et al*., 2014). Whereas WHC firstly decreased with increase in temperature and time and then increased with increase in temperature and time FRAP of fibre concentrate from carrot pomace was decreased with increase in temperature and time.

Optimization of fibre concentrate

Optimization of fibre concentrate was done for TDF, FRAP, WHC and OHC using Box Behnken Response surface methodology. The optimum process parameters obtained for fibre concentrate preparation from carrot pomace were : temperature 90°C, time 15 min and water to sample ratio 8.94 which gave fibre concentrate having TDF content 74.72 %, FRAP activity 22.28 mg/g, WHC 8.03 g/g and OHC 2.56 g/g. The suitability of these optimal extraction process variables was tested by performing the experiments under these conditions The experimental results were found closed to optimized selected value with a variation 1.55% in TDF, 1.30% in FRAP, 1.74% in WHC and 2.35% in OHC (Table 4).

Characterization of developed fibre concentrate prepared under optimized conditions

The analysis of fibre concentrate prepared under optimized conditions has been given in Table 5. The amount of IDF and SDF fibre concentrate was 54.55±0.12 and 19.01±0.13, respectively having the IDF to SDF ratio 2.87. SDF content of fibre concentrate was higher than guava fibre (1.8 %), Ruby grape fibre (4.57 %) and Granny Smith apple fibre (4.14 %) and royal gala apple fibre (14.33 %) (Figuerola *et al* 2005). DF concentrate could be a good source of natural antioxidants, due to presence of phenolic compounds. Total phenols and flavonoids were found to be 1.30±0.02 and 0.75±0.01 mg/g, respectively. By-product may contain many compounds which exhibit

Table 5. Physico-chemical, biochemical, antioxidative and functional attributes of fibre concentrate prepared under optimized conditions

Physico-chemical	Moisture (%)	3.33
	Colour 'L'	68.9±0.12
	Colour 'a'	+4.6±00
	Colour 'b'	+21.3±0.06
Biochemical	IDF (%)	54.55±0.12
	SDF (%)	19.01±0.13
	SDF:IDF	01: 2.87
	Crude protein (%)	7.40±0.05
	Crude fat (%)	1.02±0.01
	Total sugars(%)	5.75±0.05
	Phenols (mg/g)	1.30±0.02
	Flavanoids (mg/g)	0.75±0.01
Antioxidative	ABTS (%)	47.32±0.21
	DPPH (%)	56.26±0.32
Functional	WSC (g/g)	22.75±0.14
	WS (g/g)	0.048±0.02

antioxidative activity, so several methods have been developed to estimate total antioxidant activities and more than one method should be used to get complete value of antioxidative capacity of phenolic compounds. The relative abilities of antioxidants to scavenge ABTS radical cation were measured by comparison with the antioxidant potency of standard amounts of trolox (6-hydroxy-2, 5, 7, 8-tetramethyl chroman-2- carboxylic acid). DPPH scavenging activity has been evaluated in order to characterize the scavenging potential of the compounds (Wang *et al*., 2007). Radical scavenging activities viz. ABTS (%) and DPPH of methanolic extracts of fibre concentrate were 47.32±0.21 and 56.26±0.32, respectively. Colour viz. higher L* values (lightness) and lower a* (redness) values indicated lighter colour of fibre concentrate.

Treatment with water rinsed colour components mainly carotenoids. The fibre concentrate exhibited 7.89±0.09 g/g sample WHC and 2.50±0.03 g/g sample OHC. The WHC of fibre concentrate (Table 4) was higher than reported for other fibre concentrate such as citrus, oat bran, apple ,date and pear DF which ranged between 3.64-6.8 g/g (Borchani *et al.,* 2011, Dhingra *et al* ., 2012b)). The high WHC suggested that this material could be used as functional ingredient in food to avoid syneresis of formulated products (Elleuch *et al*., 2008). The OHC of fibre concentrate was higher than peach DF concentrate where OHC was 1.11.g oil/g sample (Borchani *et al*, 2011), The OHC of value was less than WHC (Table 4) because of the presence of lower SDF content (Borchani *et al* 2011). OHC has a significant role in flavour retention of food products and it also affects the food formation processes, especially in the meat industry. OHC influences other functional properties of food products including their emulsifying capacity. WSC for carrot pomace fibre concentrates was 22.75 g/g which could be related to IDF content. Structural characteristics and the chemical composition of the fibre (water affinity of its components) play important roles in the kinetics of water uptake. According to Lopez *et al.* (1996), water could be held in capillary structures of the fibre as a result of surface tension strength and also water could interact with molecular components of fibre through hydrogen bonding or dipole forms. Femenia *et al.* (1997) reported higher values of WSC (16.9–17.5 ml/g) for cauliflowers. Functional properties of any dietary fibre depend upon its SDF/IDF ratio, size of particle, extraction parameters and source of plant (Jaime *et al.,* 2002). The main properties of commercial fibre should have more than 50% TDF content, less than 9% moisture, low fat, low caloric value (Figuerola *et al.,* 2005), sufficient amount of antioxidative compounds and physiochemical properties (Larrauri, 1999), Thus, the fibre concentrate from carrot pomace can be used as a source of fibre in commercial food formulations.

To conclude, the carrot pomace fibre concentrate was prepared and process parameters were optimized using response surface. Temperature and time of treatment had significant effect on the yield as well as on antioxidative and functional properties of the fibre concentrates whereas water to sample ratio did not show any significant effect on the studied responses. The optimum process parameters i.e. temperature 90°C, time 15 min and sample to water ratio 8.94 resulted in TDF content 73.56 %, FRAP activity 21.97 mg/g, WHC 7.89 g/g and OHC 2.50 g/g. Thus, these concentrates exhibited high purity, high antioxidative activities and excellent functional properties. These are certainly suitable to be used as a functional ingredient and can be incorporated as fibre supplement in food products.

Authors' contribution

Conceptualization and designing of the research work (SB, MSA); Execution of Lab experiment and data collection (RK); Analysis of data and interpretation (SB, RK); Preparation of manuscript (SB, MSB,SS).

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